



## Water quality assessment and policy evaluation of Lake Danao, Philippines

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### ABSTRACT

The current condition of Lake Danao in San Francisco, Cebu, Philippines, specifically on water quality, policies, and community participation as bases for lake management is the focus of this study. Basic parameters to test the water quality were examined on-site. Some parameters were tested in the water laboratory for analysis. Policies were obtained from the records of the Local Government Unit (LGU) of the municipality of San Francisco about the utilization of Lake Danao. Municipal ordinances were present and available intended for the conservation of the lake. Community participation was also assessed and evaluated. Moreover, the GERMADAN framework was utilized in this study for successful lake management. Results showed good lake water quality except for total phosphorus, which indicates nutrient leaching from fertilizers and animal manure within the periphery of Lake Danao. Policies were existing but needed thorough monitoring for proper implementation. People's organizations for lake conservation emerged but not that stable and active to pursue the organization's objectives. To appropriately manage the lake, based on results, recommendations such as the making of policies prohibiting the use of chemical fertilizers and other agricultural activities which may degrade the quality of the lake, strengthening the existing policies through conducting seminars to develop an awareness of the people and to encourage the public to participate in the conservation and management of the lake for its betterment should be implemented faithfully.

**KEYWORDS:** *assessment, evaluation, policy, management, water quality*

### 1 INTRODUCTION

Lake Danao is one of the greatest treasures of the people of San Francisco, Cebu, Philippines. It is the only natural lake in the entire region aside from being the longest and largest lake in the Visayas. Lake Danao is known as one of the cleanest lakes in the Philippines (Tanduyan and Bontia, 2001). The lake showcases its

natural and environmental representations. It is a lake full of biodiversified flora and fauna.

In Lake Danao, fish such as tilapia, goby, carp, mudfish, theron, freshwater catfish, and climbing perch can be found. Along the lake's periphery, Hydrilla, water lily, water hyacinth, kangkong, nipa, soli-soli, corn, rice, coconut, cassava, banana, ampalaya, eggplant, beans, okra, and pepper grow (Tanduyan et al., 2016).

To preserve the lake's biodiversity, good water quality must be maintained, and the water must be free of pollution. According to Ceballos et al. (2015), biodiversity is declining globally even if measures are in place. Human activities such as habitat fragmentation and resource overexploitation are to blame for the dwindling biodiversity (Tilman et al., 2017). Because biodiversity is depleting, conservation of the remaining resources is one of the greatest concerns in biodiversity (Tulloch et al., 2015).

The people living near the lake are very blessed for their survival in their daily living activities. Majority of the people are engaged in fishing and farming as their primary livelihood. People can also generate income from the lake, such as nipa making used as roofs for houses and soli-soli weaving as mats and decorative purposes. Municipal Ordinance No. 2004-023 adopts the fisheries management plan to ensure food security for the people of the municipality and the Filipinos in general. Though the welfare of the people is prioritized, there should be control in this provision to conserve resources. These ecosystem services are the benefits that people acquire from the ecosystem. The ecosystem and biodiversity offered numerous benefits to people. As a result, tying natural resources to help the broader public socioeconomically can lead to long-term ecosystem management (Guerry et al., 2015).

Wetlands are the most progressive environment globally, and they have played a critical part in people's livelihoods in Africa (Rebelo et al., 2010). The services and goods that wetlands can provide to people are food, agriculture, fisheries, recreation, and water quality maintenance (Seelig and DeKeyser, 2006). Furthermore, wetlands can boost agricultural output even more (McCartney and Houghton, 2009).

Since Lake Danao is ecologically feasible and economically viable, proper management should be

emphasized. Nevertheless, the population of the people is continuously increasing. Therefore, many mouths to feed may result in over-extraction of resources from the lake. Furthermore, Lake Danao is now a tourist spot. Many tourists from different places come and visit the lake. There are already existing policies through municipal ordinances governing the limitation of the activities in the lake. However, regular monitoring is very imperative to control such activities.

Likewise, water policies demonstrate the use of authority in water-related operations (Kuzdaz and Wiek, 2014). Policy implementation controls and manages conflicts (Gehrig and Rogers, 2009). People and all stakeholders can make better decisions on water policies if all organizations, laws, and regulations are institutionally structured (DE Stefano et al., 2014). Aside from the water policies, there are many community organizations working to protect and conserve Lake Danao, according to Tanduyan et al., (2016). If the goal is to manage lake water practices, landowners, managers, and the general public must all work together (Thornton and Laurin, 2005).

Lastly, based on the people living near Lake Danao, crocodiles, leeches, and turtles were seen in the lake before. With this idea, there must be a reason why they cannot be found anymore in the lake today. If this situation is taken for granted, biodiversity in the lake will be at stake. According to the locals, fish like tilapia were very abundant before as compared to today. In addition to this, wild duck "gakit," also known as Little Grebe, is another species found in the lake that is decreasing in number. There may be more species found in the lake. Unfortunately, only a few people came to study the lake. Lake Danao needs further research for better management.

The people living near Lake Danao, LGU of San Francisco, Cebu, and future researchers who wish to study further Lake Danao would benefit from this present research. Hence, this study was conducted to assess Lake Danao's water quality and evaluate policies to determine appropriate lake management initiatives.

## 2 MATERIALS AND METHOD

### Study Site

Lake Danao is formed as a number 8 with 649 ha with 4047 sq. m islet at the center. It is located within the vicinity of the 6 out of 15 Barangays of San Francisco, Cebu, namely Union, Northern Poblacion, Sta. Cruz, Esperanza, Campo, Cabunga-an. Twelve sites in the lake were determined for water testing. Two specific sites from each barangay were tested. The first site is within 10 – 20m from the lake shoreline and the other water sample tested within 50 to 70m.

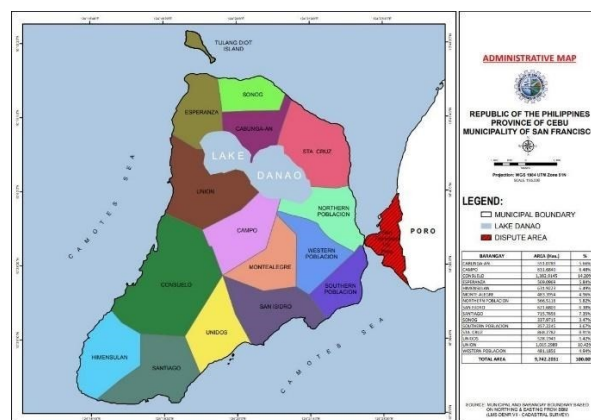


Figure 1. Location Map of San Francisco, Cebu (LMS-DENR VII – Cadastral Survey)

### Framework of the Study

The study utilizes the GERMADAN as the research framework (Soeprbowati, 2015). GERMADAN is an integration from the six pillars of International Lake Basin Management (ILBM) made by International Lake Environment Committee Foundation (ILEC, 2007) to guide the stakeholders and managers to gain successful management of the lake. The current study focused on the science and technology application through water quality analysis and governance for lake conservation through policies. Community empowerment comes along with the policies since people's organization is one of the municipal policies for lake conservation.

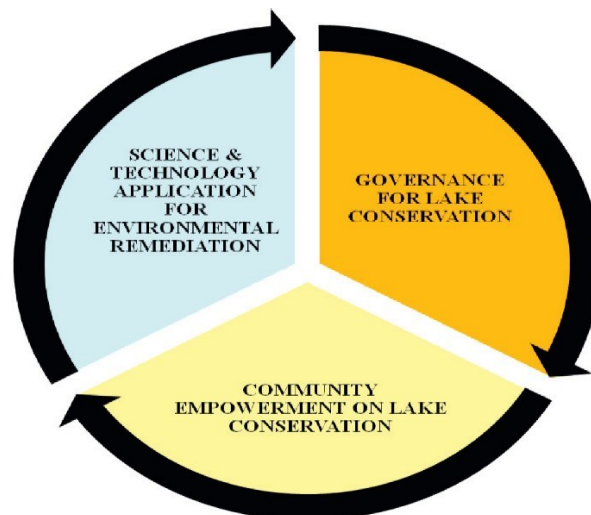


Figure 2. GERMADAN Framework (Soeprbowati, 2015)

### Data Collection for Water Quality Analysis

An ocular visit to the site was implemented. Informal interviews with a few people living near the lake and setting an appointment with the tourism officer of the municipality of San Francisco to get pertinent information about Lake Danao were conducted. The

water sample was extracted from the lake and transported to Cebu City at the University of San Carlos (USC) water laboratory to analyze Ammonia-N, Total Phosphorus, and Total Suspended Solids. The sample was collected from the middle portion of the lake as a common reference point for all the barangays surrounding Lake Danao.

Other parameters such as Secchi depth, pH, dissolved oxygen, temperature, and salinity were conducted on-site with the help of the LGU and the fisher folks within the lake area. Materials used to determine such parameters were Secchi disk, pH meter, DO meter, thermometer, and refractometer. Lake Danao is a freshwater body classified as class C used for fishery propagation, recreational water class II (boating, fishing, or other similar activities), and agricultural purposes.



Figure 3. On-Site Water Testing

#### Policies

Municipal policies of San Francisco for Lake Danao management.

- Municipal Ordinance No. 93-020 prohibits the hunting of birds within the municipality.
- Resolution No. 68-93, Lake Danao, is declared as the Fauna Sanctuary of the municipality.
- Resolution No. 93-011 mandates the soli-soli weavers and cutters to secure a mayor's permit.
- Resolution No. 48-96 states that penalties will be subjected to those acts resulting in lake pollution.
- Municipal Ordinance No. 96-004 in relation to RA 1067 Art. 51-52 prohibiting residential construction and structures 20 m from lakeshore for easement of water and buffer zone.
- Municipal Ordinance No. 96-005, forbidding the use of motorized boats in the lake.
- Municipal Ordinance No. 99-02, policy declaring every September 18 as the coastal clean-up day in all marine and lake waters of the municipality.
- Resolution No. 73-99 mandating the captains of the six barangays around the lake to spearhead activities for protection and conservation.

- According to RA 9147, Resolution No. 020-2005, conservation and protection of wildlife resources and their habitats.
- Municipal Ordinance No. 2009-061, integrated and ecological solid waste management of the municipality
- Municipal Ordinance No. 99-006, according to RA 8550, implements all laws on fisheries and aquatic resources, rules, and regulations of the municipality.
- Executive Order No. 02-2003 San Fran Lake Watch was created as an organization to safeguard, protect and help conserve the lake (Tanduyan et al., 2016)

### 3 RESULTS AND DISCUSSION

The population has increased specifically in the barangays surrounding the lake. This implies that there is tremendous activity in the lake which likely increases in the ensuing days. In the case of Lake Timsah, human population growth is linked to declining water resources and an increase in organic pollution (El-Sehery H.A. et al., 2018).

Table 1. Census of Population from 2010-2015

Barangay	Population as of 2010 survey	Population as of 2015 survey
Cabunga-an	1764	2226
Campo	2517	3123
Esperanza	5629	6370
Northern Poblacion	3779	4786
Sta. Cruz	4717	5465
Union	4721	5023

Results showed acceptable values with average pH of 9.22, DO 12.59 mg/L, temperature of 33°C, salinity 0 ppt, and Secchi depth of 2.54 m. In general, the pH of the lake would drop from 6.0 to 9.0 (DENR Administrative Order 2016-08). The breakdown and photosynthetic processes in the lake are responsible for dissolved oxygen (Sheela, A.M. et al., 2011). Fish requires 3-5 mg/L of dissolved oxygen to survive. The biological activity of the lake, mainly fish, may be harmed if the dissolved oxygen concentration is less than 6 mg/L. The temperature of the water also has a significant impact on organism growth. Biological activity is proportional to water temperature (Sheela, A.M. et al., 2011). A ten percent rise is acceptable (DAO 2016-08). Salinity indicates the presence of seawater or contamination from industrial waste. The rising salinity of the lake impacts agriculture (James et al., 2013). It causes toxicity, which leads to a loss of biodiversity and a deterioration in water quality. Secchi depth is a cloudiness indicator that assesses the growth of plankton and sediments suspended in the water. Low dissolved oxygen is a significant concern in lakes with a shallow Secchi depth.

Table 2. Average Water Testing Results from Each Site (10-20 m and 50-70 m from Lake Shoreline)

	Sta. Cruz	Northern Poblacion	Campo	Esperanza	Union	Cabonga	Average	Normal Reference Values
<b>pH</b>	9.24	9.29	9.24	9.18	9.23	9.16	<b>9.22</b>	***6.5 to 9.0
<b>DO</b>	12.42 mg/L	13.86 mg/L	11.84 mg/L	12.96 mg/L	12.28 mg/L	12.17 mg/L	<b>12.59 mg/L</b>	***5 mg/L (minimum)
<b>Temp.</b>	31°C	34°C	35°C	32°C	33.5°C	32.5°C	<b>33°C</b>	*** 25-31°C
<b>Salinity</b>	0 ppt	0 ppt	0 ppt	0 ppt	0 ppt	0 ppt	<b>0 ppt</b>	* 0-5 ppt
<b>Secchi Depth</b>	1.44 m	0.90 m	1.14 m	3.85 m	3.0 m	4.89 m	<b>2.54 m</b>	** < 1ft are subject to low levels of DO

\* <http://www.alken-murray.com/TESTS03.htm>

\*\*<https://extension.psu.edu/interpreting-water-tests-for-ponds-and-lake>

\*\*\*DENR Administrative Order No. 2016 – 08

Ammonia-N and total suspended solids showed values within normal limits. Unfortunately, total phosphorus is relatively high, suggesting pollution from fertilizer, manures, or other waste products and detergents. Ammonia is dangerous to fish at levels more than 0.03 mg/L. However, for freshwater, 0.05 mg/L is acceptable (DAO 2016-08). Furthermore, suspended particles will restrict the amount of light available to vegetation. It darkens the water and allows more heat from the sun to be absorbed (Sheela, A.M. et al., 2011). Total phosphorus levels greater than 0.03 mg/L might cause algae to thrive, reducing the amount of dissolved oxygen available for biodiversity survival.

In agricultural wetlands, biodiversity increases without fertilizers or pesticides (Wondie, 2010). Appropriate conservation in agricultural wetlands can help to ensure that ecosystem functions are maintained (Verhoeven and Setter, 2009). Inappropriate usage of wetlands can cause harm and may have long-term consequences (Moges, 2016).

Table 3. Parameters Tested in Water Laboratory

Parameter	Method Used	Result	Reference Normal Values
Ammonia-N	*Phenate Method, Calorimetric	0.025 mg N/L	*** 0.05 mg/L
Total Phosphorus	*Ascorbic Acid with Persulfate Digestion	0.069 mg P/L	** < 0.025 mg/L
Total Suspended Solids	*Gravimetric	6.00 mg solids/L	***80mg/L

\* APHA, AWWA, WPCF, Standard Methods for the Examination of Water and Wastewater, 22<sup>nd</sup> ed., USA; APHA (2012)

\*\* <http://www.alken-murray.com/TESTS02.htm>

\*\*\* DENR Administrative Order No. 2016 – 08

Findings revealed that even with the existing policies, people are still violating these regulations. They could be unaware of the policies implemented by the LGU of San Francisco. Based on the findings, these policies should be strengthened to conserve Lake Danao. The people should be involved in strengthening these policies especially with the extraction of resources (sol-

solis, fishes and other ecological services) from the lake for conservation purposes. The animal bathing in the lake should be strictly prohibited. Furthermore, washing clothes can contribute to the increase of phosphorus in the lake that may soon cause biodiversity loss due to algal growth and decrease of dissolved oxygen levels. Moreover, pollution is inevitable, especially if establishments are within the easement of water or buffer zone. The development of tourism should not be a reason for increased lake pollution. Waste should be disposed of properly. In addition, illegal fishing should be stopped to increase the abundance of fishery resources in the lake. Lastly, people within the lake area should be empowered to help

Table 4. Municipal Policies for Lake Conservation and the Observed Violations

Ordinances	Content	Remarks
Resolution No. 93-011	<i>Soli-soli</i> cutters and weavers to secure a mayor's permit	Upon interview with the assistant officer of the municipal treasurer, no permit was issued to the <i>soli-soli</i> weavers association. There are still <i>soli-soli</i> mats in the local market. It implies that they used <i>soli-soli</i> even without permit.
Resolution No. 48-96	Penalties will be subjected to those acts resulting in lake pollution	Based on the informal interviews with the locals nearby the lake, seldom, but there are still people washing their clothes in the lake and bathing animals in the lake, which may cause the water to be polluted.
Republic Act 1067 Art. 51-52	Prohibiting residential construction and any structures 20 m from the lakeshore	Based on the researcher's ocular observation, there are already commercial establishments within the easement of water or buffer zone. Unfortunately, there is a particular establishment constructed within the lake.
Executive Order No. 02-2003	San Fran Lake Watch	The organization is not active anymore. Upon interviews with the people living nearby the lake, no people's organization is safeguarding the lake for conservation.
Municipal Ordinance No. 2009-061	Integrated and ecological solid waste management of the municipality	Tourists significantly contributed to pollution (waste products of any kind) as observed during frequent visits especially in Barangay Union where the Lake Danao Park is located.
Municipal Ordinance No. 99-006, pursuant to RA 8550	Implementing all laws on fisheries and aquatic resources, rules, and regulations of the municipality	During on-site visit, the researcher has personally seen fine mesh nets in catching fishes in the lake. Therefore, there are still hard-headed people who are using fine mesh nets with less than 3cm violating the fishery laws.

preserve and conserve Lake Danao. If all these violations

prevail for a long time, there will be biodiversity loss in the near future. Biodiversity is decreasing globally Ceballos et al. (2015). Human activities are one of the major culprits of depleting biodiversity (Tilman et al., 2017). Conservation of the remaining resources is a major concern in biodiversity (Tulloch et al., 2015). Improper utilization of wetlands in which lakes are part of it can cause harm and may have long-term negative impacts (Moges, 2016).

#### 4 CONCLUSIONS

Generally, based on the results, lake water quality is excellent except for total phosphorus, which indicates the presence of fertilizers and animal manure from agricultural activities nearby the lake. Despite existing policies, it still needs to be monitored for proper implementation to protect and conserve the lake. Moreover, due to the limited studies of Lake Danao, it needs to be more researched to improve and identify advancements to manage the lake appropriately. Lastly, if the lake is further mismanaged, many people will suffer socioeconomically due to biodiversity loss.

Aside from the provision of several environmental benefits, well managed lakes can enhance the people's quality of life and can develop the economy in many ways. Lakes can minimize the effect of droughts and floods through containing more water storage and utilizing it during water shortages. Moreover, it can also replenish groundwater and conserve the biodiversity of species within the lake. Therefore, if the lake is well managed, people can enjoy the benefit from the lake's ecological importance.

Lake Danao can also offer opportunities for recreation, tourism, and is also treasured by many for its traditional and historical asset. It has also the potential to be a source of raw water for drinking. Lakes can be utilized in agriculture as a source of irrigation. To sum it up, a lake is far more than just a body of water where people can have recreational activities. It is an essential ecosystem that, if well-managed, can maintain a sound environmental balance of aquatic life, provides enjoyment, and helps meet socioeconomic needs of many people. Practicing lake stewardship in making the lake healthy for everybody, especially those who rely on its benefits.

#### RECOMMENDATIONS

- Information dissemination and education seminars should be conducted as soon as possible. If taken for granted, the once one of the cleanest lakes will become one of the polluted lakes in the Philippines.

- Strengthening, proper implementing and monitoring of the policies to preserve and conserve Lake Danao especially policies such as Resolution No. 93-011 (Soli-soli cutters and weavers to secure a mayor's permit), Resolution No. 48-96 (Penalties will be subjected to those acts resulting in lake pollution), Republic Act 1067 Articles 51-52 (Prohibiting residential construction and any structures 20 m from the lakeshore), Executive Order No. 02-2003 (San Fran Lake Watch), Municipal Ordinance No. 2009-061 (Integrated and ecological solid waste management of the municipality), Municipal Ordinance No. 99-006, pursuant to RA 8550 (Implementing all laws on fisheries and aquatic resources, rules, and regulations of the municipality).
- Laws that forbid the use of chemical fertilizers and raising animals within the easement of water or buffer zone could be proposed.
- The community may be empowered to participate in the preservation and conservation of the lake.
- More research is encouraged to provide better management.
- Further study that assesses the presence of heavy metals and other essential parameters in the lake is encouraged.

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